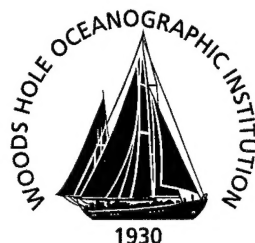


Woods Hole Oceanographic Institution



Digital Data Logging and Processing, Derbyshire Survey, 1997

by

Jonathan C. Howland

July 1999

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Technical Report

Funding was provided by the National Science Foundation under Grant No. OCE-9627160 and a Memorandum of Agreement between the United States Government and the United Kingdom Department of the Environment, Transport and the Regions.

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DIGITAL DATA LOGGING AND PROCESSING

DERBYSHIRE SURVEY, 1997

1. INTRODUCTION

In 1997, the Deep Submergence Group (DSG) of the Woods Hole Oceanographic Institution (WHOI) surveyed the wreckage field of the *M.V. Derbyshire*. The motivation for the survey and its results are described elsewhere (Williams et al, 1998). The purpose of this report is to describe the digital data logging and processing systems that were used by the Deep Submergence Group during the survey. The report is divided into four sections: this Introduction, a description of the collection mechanisms, a description of the processing schemes and series of appendices. The appendices include a glossary of terms, a description of data formats, and a comparison of electronic still camera processing choices. Readers desiring information on the equipment used, on the operations, or on the analysis effort performed by the on-board Inspection and Verification (I & V) Team or by the Assessors ashore are directed to (Williams et al, 1998), (Ballard, 1993) and (Bowen, et al, 1993).

2. DATA COLLECTION

Three different underwater vehicles were used during the survey, the DSL-120 towed sonar, the Argo II towed imaging sled, and the Jason ROV. Due to the differing natures of the vehicle's telemetry systems and sensors, there were differences in logging and processing methodologies.

2.1. SERIAL DATA LOGGING

For the purposes of this report, serial data is defined as that data which is usually represented by a time series and is sent to the data logging systems as a single stream of digital bits. It is usually sent via RS-232, a transmission standard that is defined for inter-device and inter computer communications. Serial data logging can be contrasted to electronic still camera data logging or sonar data logging primarily by the nature of the data being transmitted.

Figure 1 shows a block diagram of the serial data logging system used for the Derbyshire survey. (Note that although some of the particular details of hardware types, etc, have changed, the current DSG unmanned vehicles serial data logging scheme remains virtually identical to that shown. The figure describes the flow of discrete pieces of information, encoded as ASCII text, between a number of computer systems. Other types of data, such as electronic still camera (ESC) images and sonar records are handled differently and will be described in later sections of this report. Figure 1 applies to all of the vehicle systems used during the survey.

The thin black lines in Figure 1 represent RS-232 communications, and are symbolic in nature. The actual wiring paths run through a patch bay in the control van to simplify routing and connections. However, the basic signal flow for most data logging can be represented by a line from the sending computer to a device called a Portmaster. The Portmaster multiplexed the RS-232 data into packets, which are sent out on an Ethernet, represented by the thick black line. (This thick line is also symbolic, as the actual network was divided into segments with switches and hubs, to isolate the data network from the rest of the shipboard traffic.

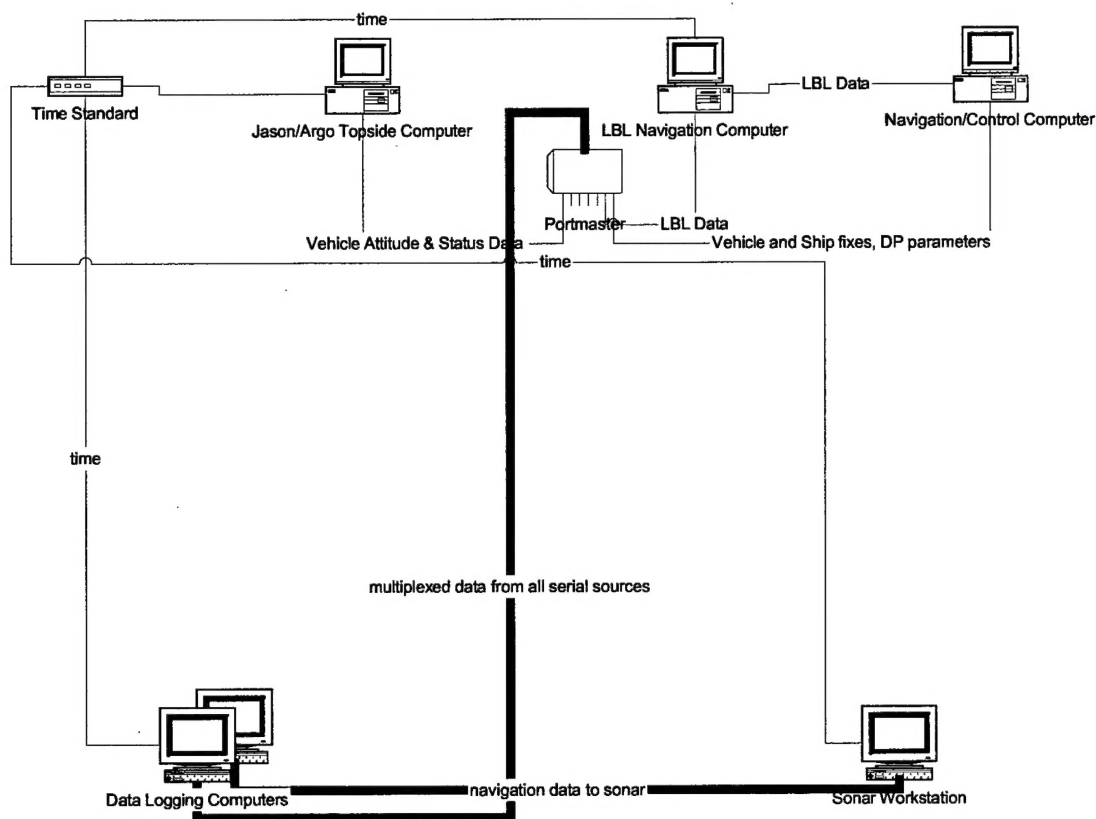


Figure 1: Serial Data Logging System

The data logging computers registered with the Portmaster to receive all data coming in on a particular serial port. They time stamped the data if necessary, logged it to hard disk, and distributed it (via network broadcast) to other shipboard computers (such as the sonar system).

A Chronolog time standard was used to insure synchronization of all the computers in the data system. The Chronolog was set to Global Positioning System (GPS) time as collected at the Navigation/Control Computer. All other systems, including the Jason/Argo topside computer and the data loggers were automatically set to the Chronolog on startup, and periodically throughout the survey. The reset interval varied between systems, but was almost always less than 1 hour, making any drift in the time reference negligible.

The data logging computers (Sun Sparc LX workstations) were used for routine monitoring of the serial data streams during the Argo II and Jason portions of the survey. Data logging watchstanders were trained to periodically check the status and size of the active files, and to contact DSG personnel in the event of any anomalies. (Note: the watchstanders were also responsible for monitoring and changing video and ESC tapes. Due to the exceptionally high workload from video systems, two watchstanders were employed for much of the Derbyshire survey.)

The DSL-120 topside computer, also a Sparc workstation, was responsible for logging DSL-120 attitude during that portion of the survey. The two LX workstations were manned

during this survey, since they were responsible for collecting navigation data as a backup to the sonar workstation recording.

The largest source of serial data during the Argo II and Jason portions of the Derbyshire survey was the vehicle topside computer. Frequent status messages, thruster command values, and vehicle attitude (pitch, roll, and heading) data flowed continually from topside to the data logger, at a rate of approximately 70 megabytes per day. The navigation system was also a continuous source of data, producing approximately 35 megabytes per day. All of the serial digital data was archived and processed daily; a later section of this report will describe those steps in some detail.

2.2. ELECTRONIC STILL CAMERA LOGGING

Electronic Still Camera data was collected on a Marine Imaging Systems Inc. (MIS) (now Imetrix Inc.) deck box every 13 seconds during Argo II operation, and recorded onto exabyte 8mm tape. Each image was stored as a 576 x 384 pixel MIS format file, in which each pixel is represented by two bytes. Part of the MIS format is a time stamp, which indicates the moment when the shutter opened and the strobe fired exposing the Charge Coupled Device (CCD) imaging chip. Upon acquisition, the raw image data was globally histogram equalized to enhance viewing, converted to eight-bit format, and displayed using the graphics output board on the topside deck box. The output of the video board was NTSC video, suitable for display on any of the monitors in the control van or throughout the ship. The raw MIS file was written by the deck box onto tape in a Unix "tar" format in separate files of fifty.

The deck box was modified by WHOI personnel to send a pulse to a Sony CRV laser disk recorder, which saved a frame of the ESC video output for later review. This laser frame was saved with a SMPTE time stamp inserted into an audio track, allowing reconstruction of the time of collection.

The objective presented to the watchstanders responsible for changing the ESC tapes was to put approximately 1000 images on each tape. In theory, each tape could hold over 4800 images, but the full capacity was never used so as to minimize the loss of data in the event of a tape failure. One thousand images also fit in fairly well with the four hour watch schedule followed during the survey, given the approximately 13 second image cycle time. Watch standers were also instructed to check with the watch leader before changing a tape, as tape changes (which took several minutes) necessitated a gap in image coverage. As a consequence, tape changes usually occurred at the end of lines, after the vehicle had been towed out of the wreckage field and was beginning a turn. In consequence, the average number of images on a tape was somewhat greater than 1300. Complete imagery coverage of the terrain below the vehicle was maintained throughout the ESC tape changes by maintaining continuous recording of video camera data during the brief periods when the ESC was off line for a tape change.

After being removed from the deck box, the ESC tape was carried to the Assessor's Lab, where it was checked into the data archive. By the end of the survey, exactly 100 raw tapes were collected. Of these 100, one tape was completely blank, due to a tape error on loading. (The error was noticed immediately and the tape changed. The blank tape was maintained as part of the data stream; since it had been pre-labeled and numbered, discarding it would cause a discrepancy between the data archive and the tape log which was kept in the control van.) A later section of this report will describe the processing and distribution of the ESC imagery.

Collection of the ESC imagery was uneventful, with one exception. At midnight on March 31, when the deck box clock should have rolled over to April 1st, it changed instead to March 32^d. When the system software which reads the clock data and time stamps the imagery encountered that date, it considered it invalid, and instead of inserting an erroneous time into the ESC record, it inserted a blank string. Fortunately, the real-time display also includes date and time, and the watchstanders quickly noticed the its absence. They summoned DSG personnel. Upon investigation of the problem, it was discovered that the deck box rolls over incorrectly on *all* month changes. The deck box time was set to June 10th, a date well beyond the planned end of the survey. In later processing, any image with a time stamp of June 10th was known to come from this erroneous period, and its date was reset to April 1st. The date in the deck box was reset to the correct date after the change of day to April 2^d.

As described, a laser disk was used to record real-time ESC output. The time stamps on these recordings were used to reconstruct the time stamps on the small number of images that were collected with a blank string in place of a date and time. Although this date change difficulty caused a flurry of activity aboard ship, it did *not* result in the loss or improper time-stamping of any data.

2.3. SIDE SCAN SONAR DATA LOGGING

Side Scan sonar data from the DSL-120 vehicle system was received via a high-speed interface on a Sun workstation. There it was time stamped (The workstation was synchronized to the Chronolog time standard) and written onto exabyte tape in its most raw form. A first stage of processing, converting raw data to amplitudes and angles was performed. A copy of this once processed data was logged across the shipboard Ethernet to hard disk, where it was archived and made available for later processing. Speed and slant-range corrected data were displayed in the control van and printed onto a hard-copy unit.

3. DATA ARCHIVING AND PROCESSING

In a manner similar to the previous section on Data Collection, this section will be broken into several parts, containing information describing the archiving and processing of Serial, or time series data, ESC data, and sonar data. The processing was performed on an integrated network of Sun (Unix) and Intel (Windows NT) workstations, connected to each other and to the real-time logging systems by a high speed Ethernet. Several Silicon Graphics workstations were also available for data review and visualization, and several

Figure 2 shows the network layout on the *R.V. Thompson*.

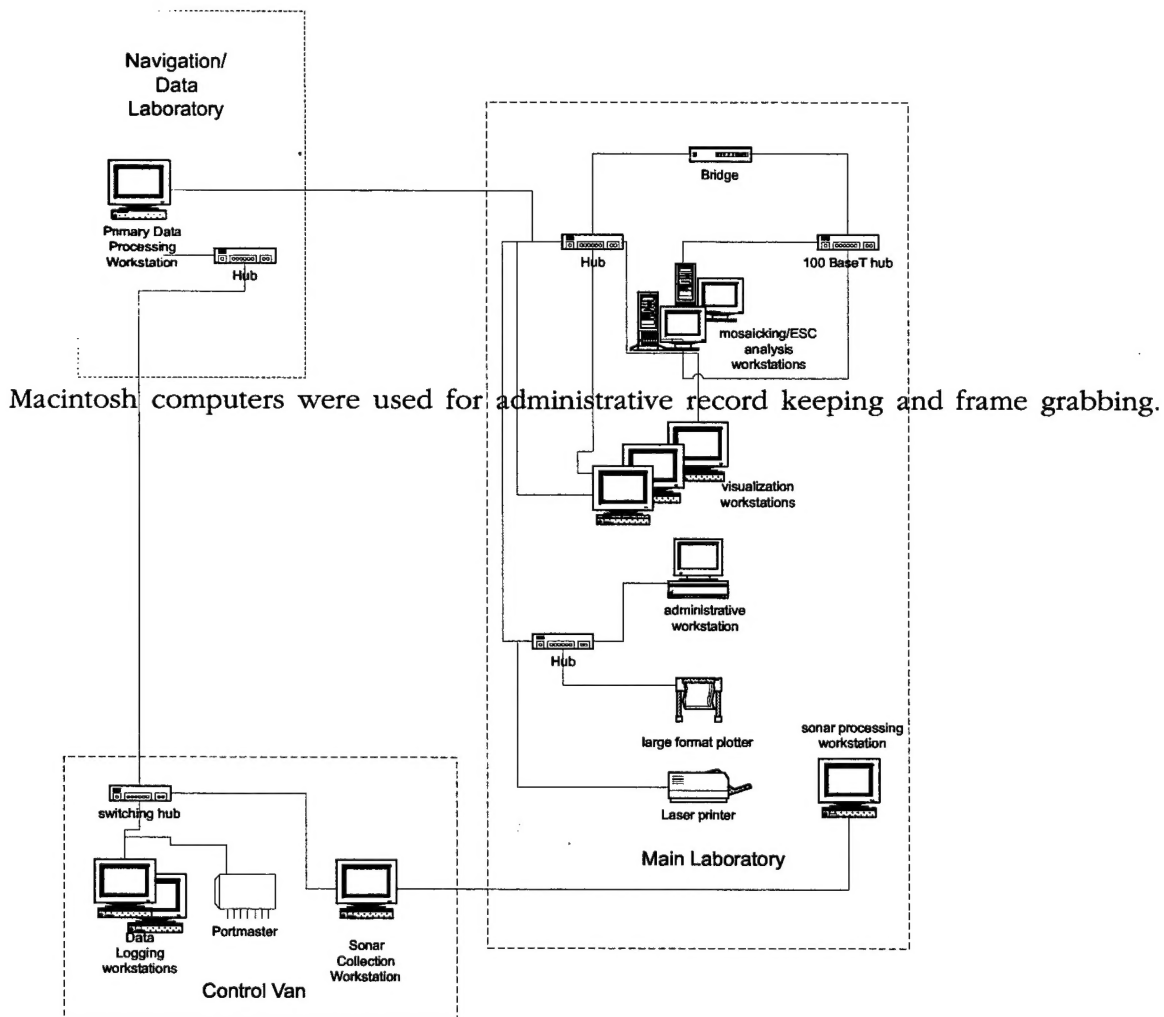


Figure 2: R.V. Thompson Network Layout

Other than those brought by DSG, significant processing resources were available on board the *Thompson*, both those belonging to the *Thompson* and those brought by members of the UK/EU team. This report will not describe those resources or any efforts undertaken using them.

3.1. SERIAL DATA ARCHIVING AND PROCESSING

Serial data archiving happened on a daily basis, using Greenwich Mean Time (GMT) midnight as a break point. Each day, shortly after Greenwich midnight, the raw files collected during the previous day were copied across the network into a raw file directory on an off-line processing Sun workstation. There they were maintained for ten days or more, with older data being periodically removed to make space. Regular exabyte tape backups of this raw data were made, ensuring that each day's raw files were written to several different exabyte tapes as redundant backups. In addition, original raw data was left on the logging computer for some time after being copied over to the raw off-line directory. This process ensured that the raw data was always available on-board ship, and multiple copies were available post-cruise.

The following file name format was used throughout the Derbyshire survey for all raw serial data from the Argo II and Jason vehicles, and for all raw navigation data:

·YYMMDD.drXXX.NNN

Where:

- YYMMDD indicates the date, in year, month, day symbology.
- "dr" is inserted by the real time data logging computer, indicating the particular serial port on the portmaster which provided the data. Due to an inconsistency between normal unix serial port naming and the "pseudo" serial ports which the Portmaster uses, the particular port number is missing from the field. This has been true for Portmaster-based logging for several years, and was determined to not be a problem. In the event that a backup data logging computer is used, "ds" is used instead, since on the backup logger, a different set of pseudo serial ports is used.
- XXX indicates the type of data, and is a string chosen by the data logging personnel at the beginning of operations. During the Derbyshire survey, the following strings were used:
 - ♦ NAV: navigation
 - ♦ JAS: Jason data
 - ♦ ARG: Argo data
 - ♦ VID: video tape recorder data
 - ♦ CRV: laser disk data
 - ♦ EVT: event data
- NNN indicates the file sequence. Usually, this number is 000, but if daily files were closed and reopened, files subsequent to the first would have ascending numbers in this position.

The raw data from the DSL-120 is contained within the sonar record format; there are no separate raw data files from this vehicle. Unless otherwise specified, all subsequent descriptions of data archiving and processing apply to data from Argo II and Jason only.

Raw data files were compressed using a standard Unix utility before archiving. Compressed files have a further ".Z" suffix appended by the utility. All Unix operating systems can use the "uncompress" command to access these files; the standard Windows utility "Winzip" can open them as well.

Data processing also happened on a daily basis. Two main types of vehicle data were processed: Navigation data, and Attitude data. Figure 3 is a block diagram of daily processing, which was a several step evolution:

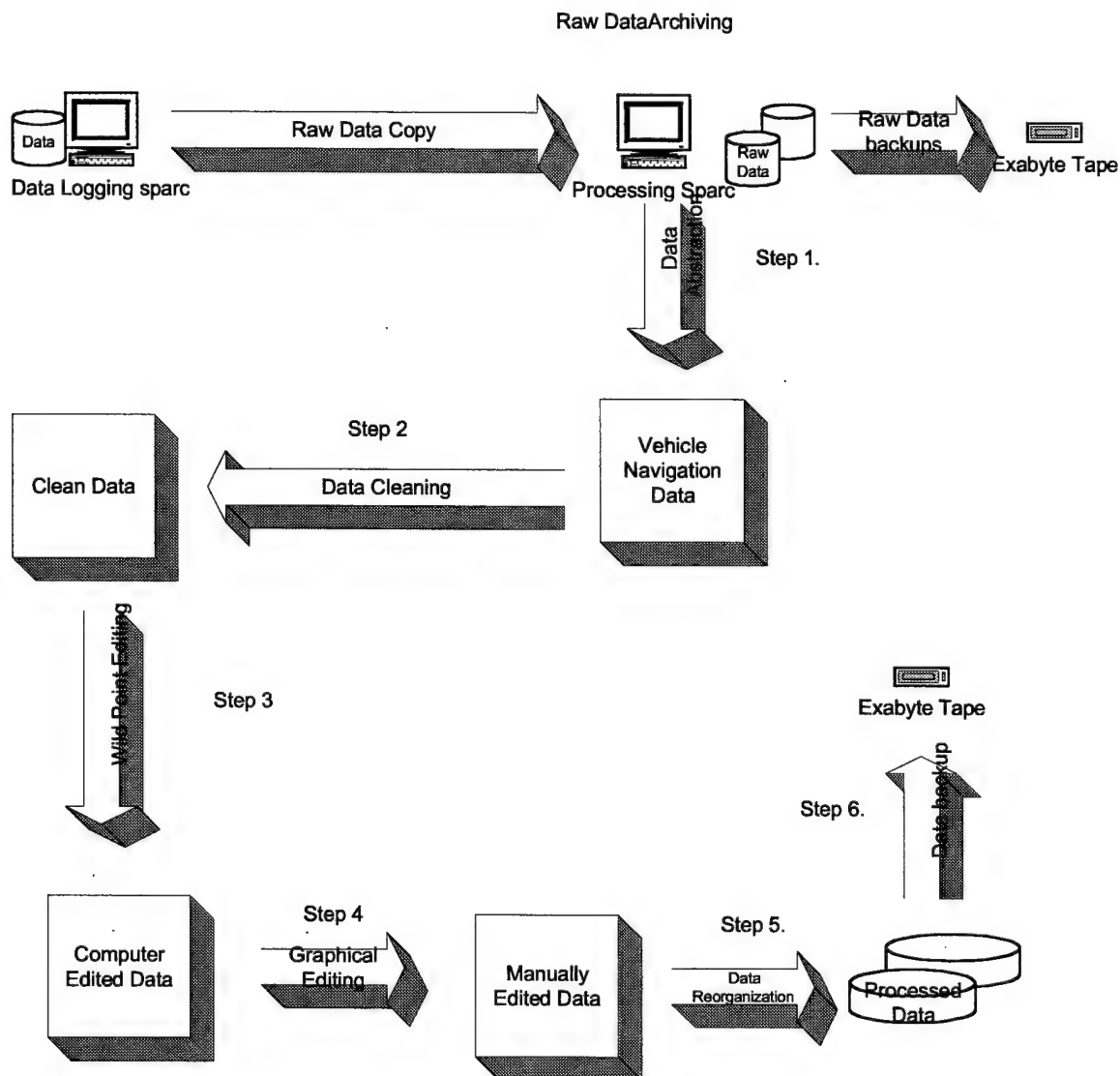


Figure 3: Daily Data Processing (serial)

3.1.1. NAVIGATION PROCESSING

1. Data Abstraction. The raw navigation data file contained many types of navigation data, from whatever vehicle was being used and from the ship. Appendix A describes the types and formats in detail. Ship data was not routinely processed. Vehicle data was abstracted from the raw file using automated scripts.
2. Data Cleaning. The vehicle data file was checked (using automated scripts) for records out of order, incomplete records, and extraneous characters. Given the simplicity of the path between the navigation system and the data logger, such problems rarely if ever occurred, but the processing step remains as a holdover from the day when inter-computer communication was not as reliable as it has become.
3. Wild-Point Editing: A simple filter examined each navigation record to ensure that the coordinates were within the survey area. A median rejection filter was used to examine the data, checking each point to be sure that it didn't differ from the median of its neighbors by more than a specified amount. A velocity filter was used to make sure that the navigation records don't indicate the vehicle travelling at an unreasonable speed.
4. Graphical Editing. The navigation data set was plotted in a custom graphical editor, both in an X/Y geographic plot, and in various time series plots (X, Y, and Z versus time). Navigation points thought to be spurious were removed during this process.
5. Data Reorganization. The fully processed navigation files were written to a "final" data directory and made available to the entire shipboard science party.
6. Data Archiving. Regular exabyte tape backups were made of the processed data.

This processing procedure was followed on a daily basis. The author performed all of the processing for the entire survey, ensuring consistency in editing. Navigation accuracy is described in (Lerner, et al, 1999).

There were several exceptions to the absolute routine of navigation processing. They were:

1. DSL-120 processing. In normal practice, the sonar processing system is used to handle navigation data from the DSL-120. However, "teething problems" with sonar software made the sonar system unable to log relay-based LBL navigation, so the standard navigation pipeline was used. However, difficulties were found in obtaining fixes on the transponder actually mounted to the sonar tow fish; instead, a transponder mounted on the main cable and ahead of the fish was used. Custom software to compute layback corrections based upon heading and the length of the tether between the clump weight and the fish was written, and this software was used in addition to that described above.
2. During the course of the Argo II survey, some dissatisfaction was expressed by members of the EU team concerning the "jaggedness" of the navigation plot. The jaggedness resulted from the use of real, non-interpolated data. It is the authors belief that in the absence of a mathematical model fully describing the dynamics of the underwater vehicle, the "raw" data (with outliers removed) is the best navigation reference—even if the track which results is not "smooth." However, for the sake of aesthetic plots, some gaussian smoothing was done, producing a smooth plot. These smoothed data were always clearly labelled and separated

form the final navigation data delivered to the Assessors, and no analysis results were based upon them.

3.1.2. ATTITUDE PROCESSING

1. Data Abstraction. Attitude data was part of the data flow from the vehicle topside processor. Appendix A describes all of this data. The attitude data was separated from the rest of the data, which was archived, but not further processed.
2. Data Cleaning. The attitude file was checked for records out of order, incomplete records, and extraneous characters. Given the simplicity of the path between the vehicle computer system and the data logging computer, such problems rarely if ever occurred, but the processing step remains as a holdover from the day when inter-computer communication was not as reliable as it has become.
3. Wild-Point Editing: A simple filter examined each attitude record to ensure that the data values were reasonable. A median rejection filter was used to examine the data, checking each point to be sure that it didn't differ from the median of its neighbors by more than a specified amount. Points which did differ significantly were deleted from the data set.
4. Graphical Editing. The attitude data set was plotted in a custom graphical editor in various time series plots (roll, pitch, heading, depth, and altitude versus time. Data points thought to be spurious were removed during this process.
5. Data Reorganization. The fully processed attitude files were written to a "final" data directory and made available to the entire shipboard science party.
6. Data Archiving. Regular exabyte tape backups were made of the processed data.

3.2. SONAR PROCESSING

As described in the section on sonar data logging, data at an intermediate stage of processing was logged across the network to a hard disk on another workstation (See Figure 4). At this workstation, several kinds of processing occurred:

1. Navigation data derived from the reprocessed layback data, as described previously, was re-merged into the data set.
2. Attitude data was processed using tools provided in the sonar processing software. The general scheme was similar to that described in Section 3.1.2, but there were no separate files produced. Corrections to attitude were maintained as part of the sonar data record.
3. Sonar data, both amplitude and bathymetry, was geo-located using the navigation and attitude data, and placed into a map grid. Multiple lines of data were merged into the same grid. Small mis-ties, well within the bounds of navigation accuracy were detected, and separate maps of each line were also produced.
4. The sonar maps were made available to the science party and used for planning Argo and Jason operations.

3.3. ELECTRONIC STILL CAMERA PROCESSING

Processing, distributing, and archiving the ESC data collected by the Argo II vehicle was the most time and computer-resource consuming task of the survey. The goal of the processing was to get high quality images into the hands of the assessors and the Inspection and Verification (I & V) team as soon as possible after the tape was removed from the deck box. Therefore, no standard daily schedule was employed. Processing continued virtually around the clock during the entire Argo survey. The following steps were followed:

1. Setup of directories and files. A logical system of file organization was set up. As each tape was processed, a new set of directories was created, minimizing the chances of tapes getting confused with each other.
2. Copy from tape to disk. The images are stored on tape in files of fifty. Although this is wise practice when using tape media (a tape error will not cause the loss of more than one file at a time, limiting the number of images lost) it makes processing cumbersome. Therefore, the tape was read all at once, and a single disk file, containing all of the data from the entire tape was built. The raw tape was removed from the processing computer and returned to the onboard archive at this time.
3. Extract images. Due to a peculiarity in the way MIS chose to write the images to tape, a block of binary zeroes had to be removed from the header of each image before the image itself could be extracted. This was done for each image. The date-time string was extracted from each image, and a new file name was created. The file name included all of the information necessary to keep each image separate from any other, and matched the following pattern:

ESC.YYMMDD_HHMMSS.IMNUM.mis

Where YY is the last two digits of the year, MM is the month, DD is the day of the month, HH is the hour, following a 24 hour system, MM is the minute, and SS is the second. IMNUM is the sequential order of the image on the tape, beginning with zero. mis indicates that this is a Marine Imaging Systems format file. This same file name pattern was followed throughout the processing, with different format type suffixes indicating different stages of processing and image formats.

A new image time file was also created, matching the image name and its time

4. Normalization. At this point, the raw image was still in a custom sixteen bit MIS format, which is not used by any other software package. Very few application software packages can use sixteen bit data at all. The goal of this step was to optimally convert the sixteen bit data to an eight-bit file in a format readily useable by other software packages.

The straightforward way to convert sixteen bits to eight is to re-map the histogram of the sixteen bit data so that it falls into 256 (eight-bit) values. However, two potentially important steps are missed if this practice is followed.

- All CCD chips have flaws that show up as artifacts on the image. In particular, the chip used in the MIS camera was fabricated in a two-stage process, and the

chip appears to have two distinct left/right halves. Figure 4 shows what is called a bias image. It represents what the chip reports as data with no exposure to light, and is frequently called a dark-current image (Newberry, 1995). The two-half effect can be clearly seen. Also seen is a distinct vertical striping, which is related to the manner in which the charge is read out of the CCD. The majority of these effects are removed by subtracting a bias image from each raw image before further processing. (Note that the gray scale ranges of the bias image shown in Figure 4 have been stretched so as to make them visible for this report. The actual image, if shown unchanged, would appear almost uniformly black due to the very low pixel values recorded in bias images.)

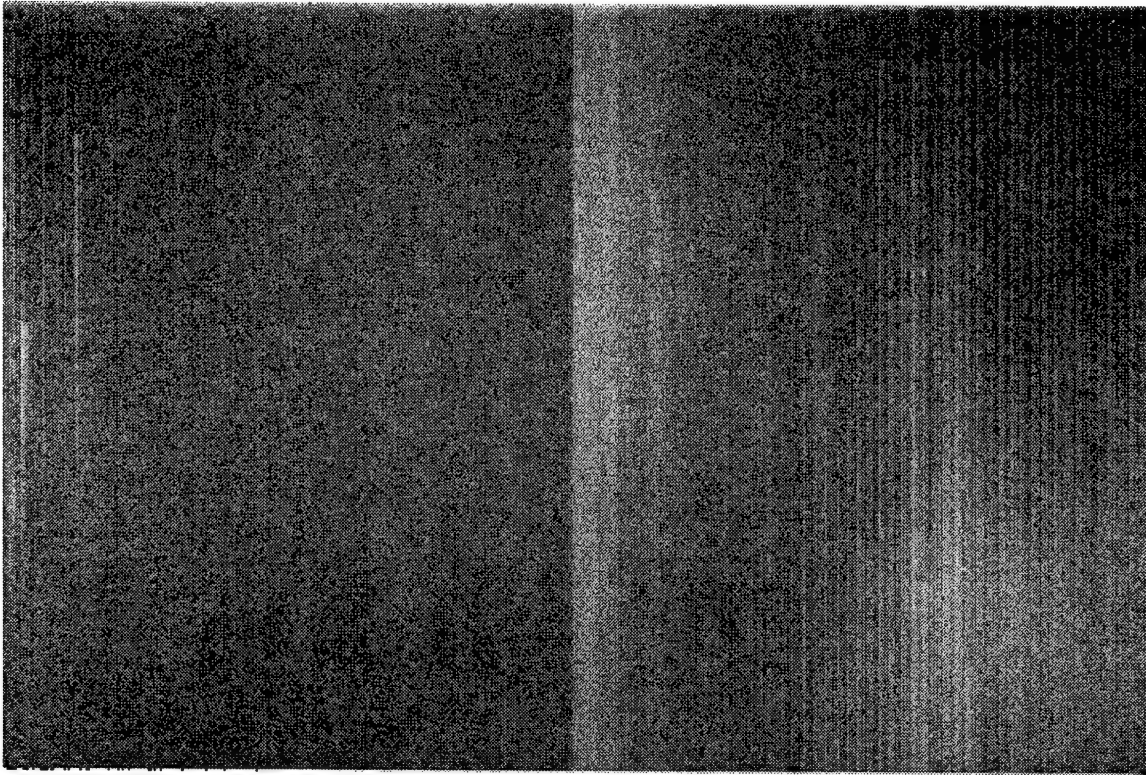


Figure 4: ESC Bias Image

- Flat fielding is an essential step in calibrating a raw CCD image. It is necessary because a given intensity of light does not produce an identical response in every pixel of a CCD array (Chromey, 1996). Variations occur due to sensitivity differences among pixels and the unique characteristics of the optical path (among other causes). The unwanted variations are removed by dividing a raw image by the flat field frame. The flat field is obtained by exposing the CCD chip to a range of grey light fields, and picking the one which most closely matches the exposures obtained by the images being adjusted.

These two processes are combined in a step called normalization. The output is an eight-bit image that accurately represents the scene imaged by the camera, which has very little artifacts induced by the camera. All of the Derbyshire survey

images were normalized. The normalized images were distinguished by a suffix of ".rf" indicating a sun raster file.

5. Histogram Specification. There were two primary ESC image products during the survey; individual images for interpretation, and photo-mosaics. Histogram specification was key to both of these.

Underwater imagery is usually characterized by uneven illumination. Shadows can be quite useful in interpretation, since they reveal differences in height and aspect. Illumination falloff, however, shows only the physics of light propagation in the water: the farther light travels, the more it is attenuated and lost. Furthermore, the uneven illumination causes a mottled mosaic, and detracts greatly from the finished product. The eyes tend to be drawn to the imperfections and apparent edges caused by illumination differences, rather than freely viewing the entire mosaic. A processing step that manipulates the gray scale values in an image to produce apparently even illumination is invaluable in adding both interpretation and mosaicking.

WHOI has been using adaptive histogram equalization, and its cousin, adaptive histogram specification for many years to successfully meet this need. Basically, each image is divided into contiguous small blocks of pixels. The histogram of each block is calculated, and either equalized or passed through the transfer function of the desired distribution. Then for each pixel of the input image, a weighted average of the transferred histograms of the surrounding blocks is calculated, and a new pixel value computed (Pratt, 1991).

Underwater surveys typically collect many thousands of images. It is entirely impractical to individually process each image, so a batch method of processing was used during the Derbyshire survey. Parameters for the histogram specification were based upon DSL experience and upon imagery collected during the first several thousand ESC images; these parameters were then used to process the entire data set. Custom software written by the author was used for this processing step. The output of the processing was an eight-bit Sun raster file.

There are several parameters which can be varied in the histogram specification process. The Woods Hole software allows modification of the following:

- Type of histogram. The choices in the WHOI software are none (which leaves the image unmodified), uniform (which is identical to adaptive histogram equalization), rayleigh (which was used for the Derbyshire survey) and exponential, which was implemented as an experiment, and has never, in WHOI experience, produced results as good as the rayleigh distribution. There is *no* theoretical justification for use of the rayleigh distribution, but it has been shown experimentally to be satisfactory.
- Alpha. The rayleigh and exponential distributions require specification of an "alpha" parameter, which modifies the specified distribution. Values are chosen experimentally, and must fall between 0.0 and 1.0.
- Region Count. This parameter specifies the number of contextual regions which will be used in histogram manipulation. If this number is chosen too

high, noise and small texture changes will be exaggerated. If it is chosen too low, illumination gradients will not be eliminated as effectively.

In order to show that the parameters chosen were reasonable, six of the images collected during the survey have been chosen for analysis. Appendix C presents these images, processed with a variety of different parameters. In retrospect, the parameters chosen during the Derbyshire survey produced the most uniformly high quality results yet seen during DSG surveys.

6. Format conversion. In order to make the data more widely useable (Sun raster files are not widely used on PC and Macintosh computers) the histogram specified files were converted to TIFF files. This conversion happened with no loss of resolution or dynamic range, it was really just a rearranging of the data. The file names of the tiff files followed the same format as described previously, with the exception that the file names ended in ".tif."
7. Data Distribution. After processing, all of the histogram-specified images were copied to Intel/Windows NT workstations for analysis and use in mosaicking. They were kept on-line as long as possible, and in no case, were they ever removed without approval of the I & V Team. Before removal, they were copied to JAZ disks for ready access in later analyses and mosaicking efforts.
8. Archival. Data from five raw ESC tapes and their associated data products were archived to exabyte tapes. All of the important results of processing were saved; the raw tapes from the deck box, the raw MIS format images, the normalized images, and the histogram specified images. Two copies of each archival tape were made; one for transferal to the U.K. and one for use at Woods Hole.
9. Coverage charts. The files containing ESC time stamps were merged with Argo position and attitude data to produce a "merge" record that contained all the information necessary to describe the position and orientation of the camera at the instant of exposure, along with its altitude. These records were used in custom DSG software to produce coverage charts that were used to monitor progress and plan operations. The ground coverage of each image was computed using vehicle altitude and other camera parameters, and plotted on a large-scale basemap of the survey area. The final version of this report appears in (Williams, et al, 1998).

The processing stream just described was followed for most of the ESC tapes. There were several exceptions, caused by occasional tape errors. In these cases, the batch processing would be interrupted by the errors, and "hand" processing would be used. In all "hand" processing, the same image normalization and histogram specification parameters were used; the only difference is that each processing step would be initiated by an operator instead of by the computer. This "hand" processing of tape or image errors was able to recover virtually all of the data which produced errors during the batch processing. Image data produced in this way is indistinguishable from that produced during the more routine batch processing.

4. DELIVERY OF DATA PRODUCTS

Throughout the survey, the results of the serial data processing just described were available to the entire survey party in a directory structure on a DSG computer. The data was used frequently by both DSG and UK/EU personnel. Copies of the final data were copied onto exabyte tape and provided to the Assessors in a Unix tar format. Additionally, copies of the data were placed onto the workstation which was delivered to the UK DETR, and also onto JAZ disks, which were turned over to the Assessors. Copies were also held by WHOI. These copies were used post-cruise to produce Compact Disks for further archiving and delivery.

Copies of all of the raw, normalized, and histogram-specified ESC imagery were made to exabyte tape and turned over to the Assessors. Additionally, a complete set of histogram-specified data was delivered on either the workstation hard disk or on JAZ disk. Copies were also held by WHOI; these were used for making copies to compact-disk for later transferal to the DETR.

An analysis system, capable of viewing and accessing all of this data was delivered to DETR after the survey. The principal component of this analysis system, the Visual software package, is documented in (Lerner, 1999).

ACKNOWLEDGEMENTS

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APPENDIX A: DATA FORMATS

This Appendix describes the formats of the data collected and processed by the Unmanned Vehicles of the WHOI Deep Submergence Group during the 1997 Derbyshire Survey.

A.1. SERIAL DATA FORMATS

Standard DSG data strings are logged as ASCII text strings that are terminated with "\n" (0D0A hex). The record has the following general format:

<STRING TYPE> <DATE/TIME RECORD> <DATA SOURCE> <DATA FIELDS> <\n>

where the individual fields are as follows:

- <STRING TYPE>

The first field of every standard DSG data string is the string-type field, a 3-letter code indicating the type of the data string. The types presently in use include:

- ◆ PAS: Platform Attitude Status - containing vehicle heading, roll, pitch, depth, and altitude data.
- ◆ PNS: Platform Navigation Status - containing vehicle position data.
- ◆ PGE: Platform Gyro Event - containing gyro events such as pilot initiated resets of gyro to current magnetic heading, and gyro power-on events.
- ◆ JTS: Jason Thruster Status containing current Jason thruster command values.
- ◆ JSS: Jason Switch Status - containing current values of various Jason on-board switches such as lights and other power controls.
- ◆ VID: A Video record, containing events pertaining to video tape start, stop, and pause times. These records were an experiment during the Derbyshire survey period, and are no longer used in the Deep Submergence Group

- <DATE/TIME RECORD>

The second field of every standard DSG data string is a date/time field that documents the Greenwich time at which the data was logged. It is in the format YY/MM/DD HH:MM:SS.SS.

- ◆ YY: Year, with no century indication
- ◆ MM: Month
- ◆ DD: Day of month, with leading zero as appropriate
- ◆ HH: Hour, on a 24 hour clock, leading zero as appropriate
- ◆ MM: Minutes past the hour, leading zero as appropriate

- ◆ SS Seconds, in decimal notation to 0.01 second resolution, leading zero as appropriate

- <DATA SOURCE>

The third field of every standard DSG data string is the data source field - indicating that the data is either from or about a particular vehicle or sensor.

- JAS Data was generated by Jason or Argo. Note that ARGO and JASON generate identical log strings. Both are referred to as "JAS" in the raw log files.
- MED Data was generated for Medea
- IMA Imagenix scanning sonar
- SHP The surface ship position
- REF The surface ship reference position
- GPS The surface ship's position according to GPS
- WRN The surface ship's position according to the WRN Military GPS receiver
- LBL The LBL navigation system

- <DATA FIELDS>

The remaining fields of every standard DSL data string contain numerical data delimited by white space.

- <\cr>

The last character of every standard DSL data string is the ASCII string termination character "\n" (0D0A hex).

A.2. SPECIFIC DATA RECORD FORMATS

A.2.1. PNS Records

PNS records are comprised of at least 9 fields:

1. "PNS"
2. Date string: YY/MM/DD
3. time string: HH:MM:SS.SS

4. source
5. coordinate frame
6. vehicle
7. X position
8. Y position
9. Z position
10. Quality Indicator (in some records)
11. Transponder Pair Indicator (in some records)

The Source field identifies the origin of the record. It can take on many forms, including WRN, which indicates a GPS receiver of some type, GPS, which also indicates a satellite receiver and LBL, which indicates an acoustic navigation fix. Navigation records use one of three coordinate frames in the fifth field: GLL, NEN, or UTM. GLL is the Geodetic Latitude and Longitude indicator. Latitude or Longitude is represented as decimal degrees, Positive North and East. NEN stands for Net East-North, a local navigation frame used in Long BaseLine (LBL) navigation. However, during the Derbyshire survey, UTM coordinates were logged in NEN records. UTM stands for Universal Transverse Mercator, a worldwide (except for very high latitudes) projection system that the DSG uses for almost all processing and mapping. The Derbyshire survey was carried out almost entirely in UTM Zone 53. Units are in meters. (A description of UTM, which includes equations for the Latitude-Longitude<->UTM transformation, is found in (Evenden, 1990).

The vehicle field identifies what is being navigated. Possible identifiers include

- SHP: The surface vessel
- JAS: The Jason vehicle
- ARG: The Argo vehicle
- MED: The Medea vehicle
- FSH: generally, the DSL-120 sonar
- EMG: The emergency transponder bottle
- RLY: A relay transponder

The last two identifiers can be used to navigate virtually any of the DSG vehicles, and have to be considered in context, knowing which vehicle was in the water at what time. The navigator on watch shifts frequencies as necessary to safely navigate the vehicle in real time.

The Z field of the navigation coordinates represents either the depth of the ship transducer (in a SHP LBL record) or the calculated acoustic depth of the vehicle being navigated.

Sample PNS Strings:

```
PNS 97/04/01 23:59:55.54 WRN GLL SHP 25.862668 133.532262 0.00 1.2 00
PNS 97/04/01 23:59:55.54 GPS UTM SHP 352931.77 2861297.19 0.00 1.2 06
PNS 97/04/01 23:59:52.00 LBL NEN SHP 352963.41 2861276.11 5.80 0.0 00
PNS 97/04/01 23:59:57.58 WRN GLL SHP 25.862663 133.532267 0.00 1.2 00
PNS 97/04/01 23:59:57.58 GPS UTM SHP 352932.26 2861296.63 0.00 1.2 06
```

A.2.2. PAS records

There are two kinds of PAS records in the data set. The first is a vehicle-based record, which is comprised of 15 fields:

1. "PAS"
2. Date string: YY/MM/DD
3. Time String: HH:MM:SS.SS
4. "JAS"
5. heading, Humphrie's mechanical gyro, degrees, true (corrected for local variation)
6. heading, KVH magnetic compass, degrees, true (corrected for local variation)
7. pitch, inclinometer, degrees
8. roll, inclinometer, degrees
9. altitude, Datasonics acoustic altimeter, meters above bottom
10. depth, Paroscientific pressure transducer, meters below surface
11. gyro correction for Humphrie's mechanical gyro, degrees
12. local magnetic variation, degrees
13. pitch, Watson, degrees
14. roll, Watson, degrees
15. 0.0
16. 0.0

The second type of PAS record is found in the raw navigation files, and is a ship's gyro record. It is comprised of ten fields:

1. "PAS"
2. Date string: YY/MM/DD
3. Time String: HH:MM:SS.SS
4. "SHP"
5. heading, ship's gyro

6. 0.0
7. 0.0
8. 0.0
9. 0.0
10. 0.0

The last five fields were always set to zero for consistency with the vehicle-originated PAS format and potential use in other DSG processing software.

All magnetic headings are logged in degrees of true heading. Magnetic headings are corrected to true headings by applying the local magnetic variation programmed that is programmed into the Jason/Argo topside computer. The sign convention of magnetic variation is

Negative = west, positive = east.

Raw magnetic heading is converted to true heading with the formula:

True heading = raw heading + current magnetic variation;

Gyro heading is logged in degrees true. The gyro is corrected for earth-rate rotation based on the latitude programmed into the Jason/Argo topside computer. The gyro drifts, sometimes over 10 degrees per hour. The pilot periodically manually resets the gyro heading to the current true heading indicated by the magnetic compass.

Sample PAS Strings:

```
PAS 97/06/24 16:39:00.07 JAS 350.6 352.3 -1.9 5.2 4.2 845.028 -23.6 1.0 -3.9066 3.4323 0.0
0.0
PAS 97/06/24 16:39:00.83 JAS 350.6 352.0 -2.5 5.0 4.2 845.015 -23.6 1.0 -4.3954 3.2968 0.0
0.0
PAS 97/06/24 16:39:01.11 JAS 350.7 352.0 -2.8 5.1 4.2 845.015 -23.6 1.0 -4.6408 3.2236 0.0
0.0
PAS 97/06/24 16:39:01.42 JAS 350.8 351.5 -2.9 5.0 4.2 845.015 -23.6 1.0 -4.6591 3.1796 0.0
0.0
PAS 97/06/24 16:39:01.89 JAS 351.0 351.5 -3.2 4.9 4.2 845.035 -23.6 1.0 -4.5273 3.1796 0.0
0.0
```

A.2.3. JTS Records

JTS records are not used in routine processing, but are logged and maintained for use in thruster analysis. They are comprised of seventeen fields:

1. "JTS"
2. Date string: YY/MM/DD
3. Time string: HH:MM:SS.SS
4. "JAS"

5. Port Horizontal (PH) thruster command in Newtons
6. Starboard Horizontal (SH) thruster command in Newtons
7. Forward Lateral (FL) thruster command in Newtons
8. Aft Lateral (AL) thruster command in Newtons
9. Port Vertical (PV) thruster command in Newtons
10. Starboard Vertical (SV) thruster command in Newtons
11. Aft Vertical (AV) thruster command in Newtons
12. 7 bit bitfield indicating power status of each vehicle thruster as follows:
 - PH power on? (0 or 1)
 - SH power on? (0 or 1)
 - FL power on? (0 or 1)
 - AL power on? (0 or 1)
 - PV power on? (0 or 1)
 - SV power on? (0 or 1)
 - AV power on? (0 or 1)
13. U Thrust command. Total commanded thrust in forward direction, Newtons.
14. V Thrust command. Total commanded thrust in starboard direction, Newtons.
15. W Thrust command. Total commanded thrust in down direction, Newtons.
16. Heading Moment command. Total commanded moment in clockwise direction, Newton-meters.
17. Jason-Argo configuration:
 - 0 = Jason deep configuration - 1HP Thrusters as forward verticals
 - 1 = Jason shallow configuration - 1HP Thrusters as laterals
 - 2 = Argo configuration - 1HP Thrusters as laterals

Sample JTS Strings:

```

JTS 98/04/20 10:00:01.58 JAS 24.6804 13.5970 5.5417 -2.7708 -14.3563 -14.3563 -
7.1781 1111111 35.4901 2.7708 -35.8907 10.5846 0
JTS 98/04/20 10:00:02.58 JAS 34.9563 3.3211 15.8176 -7.9088 -14.3563 -14.3563 -
7.1781 1111111 35.4901 7.9088 -35.8907 30.2116 0
JTS 98/04/20 10:00:03.59 JAS 29.0642 9.2131 9.9255 -4.9628 -14.3563 -14.3563 -
7.1781 1111111 35.4901 4.9628 -35.8907 18.9578 0

```

A.2.4. JSS Records

JSS records are not processed during normal operations. They represent system status, and are comprised of ten fields:

1. "JSS"
2. Date string: YY/MM/DD
3. Time string: HH:MM:SS.SS
4. "JAS"
5. ten-bit bitfield indicating the power status of the following devices: (0=off, 1=on)
 - pan-tilt
 - gyro compass
 - magnetic compass
 - pressure depth sensor (Paroscientific)
 - acoustic altimeter
 - manipulator
 - electronic still camera
 - Imagenex sonar
 - sidescan sonar
6. four-bit bitfield indicating the power status of the following devices: (0=off, 1=on)
 - light circuit 1
 - light circuit 2
 - light circuit 3
 - light circuit 4
7. four-bit bitfield indicating the power status of the following devices: (0=off, 1=on)
 - video circuit 1
 - video circuit 2
 - video circuit 3
 - video circuit 4

8. two-bit bitfield indicating the power status of the following devices: (0=off, 1=on)
 - science bus 1
 - science bus 2
9. A two-integer field indicating the state of the two subsea video switches. Two of the video channels from subsea to topside are selectable via two subsea video switches to any of four possible subsea cameras. The two digits of this field indicate the switch state of these two video switches.
10. Integer frame count for the 35mm film camera.

Sample JSS Strings:

```
JSS 98/04/22 08:06:35.68 JAS 0101101100 0000 1111 00 31 0
JSS 98/04/22 08:06:45.68 JAS 1101101100 0000 1111 11 31 0
JSS 98/04/22 08:06:55.69 JAS 1101101100 0010 1111 11 31 0
JSS 98/04/22 08:07:05.71 JAS 1101101100 0010 1111 11 31 0
```

A.2.5. VID Records

VID records are comprised of 5 fields:

1. "VID"
2. Date string: YY/MM/DD
3. Time string: HH:MM:SS.SS
4. "VID"
5. Event string, in the form ACTION-DECK_TYPE_DECK_NUMBER, where action is STOP or REC, deck_type is HI8 or HIRES, and the number is a sequential number assigned at installation.

VID records were created by a Crestron control panel, which is a digital device often used to control devices such as tape decks in auditoriums and other facilities. WHOI used a Crestron as an experimental way to control the multitude of video decks which were used during the Derbyshire survey, but has not continued the practice.

A.3 ELECTRONIC STILL CAMERA DATA FORMATS

The electronic still camera images which were delivered to DETR were in several formats. The first is the custom Marine Imaging Systems format. Definition of this format is available from the author.

The next two formats are sun raster files and tiff files. Ample descriptions of these formats can be found in (Murray and VanRyper, 1994) or any other graphics reference.

A.4 SONAR DATA FORMATS

Definitions of the sonar data format is available from the author or from the vendor of the software used for real-time collection and post processing (Oceanic Imaging Consultants, Honolulu, Hawaii).

APPENDIX B: GLOSSARY OF ACRONYMS & TERMS

Amplitude Data: The term used to describe acoustic backscatter strength received at a side scan sonar receiver. Compare to Bathymetry data.

Attitude Data: vehicle roll, pitch, and heading data

Bathymetry Data: Measurements of the depth of the sea floor. Used in this report to describe one type of data from the DSL-120 side-scan sonar.

CCD: Charge Coupled Device, the imaging system used in an electronic still camera

Chronolog: A precise clock used as a time standard in the DSG control van.

Clump: a heavy weight attached to the main fiber optic cable, behind which the DSL-120 is towed using a flexible cable.

CRV: Continuous Recording Velocity, a type of laser video disk.

Data Logging Workstation: One of two Sun Sparc LX workstations used in the control van to collect, store, and distribute serial data.

Data Processing Workstation: A Sun Sparc LX workstations which was located in the computer Laboratory and was used to process Serial data, as well as ESC data. The Sonar Processing workstation was also used for these tasks when not busy processing sonar data

DETR: The Department of the Environment, Transport and the Regions.

DSG: Deep Submergence Group.

DSL: The Deep Submergence Laboratory

ESC: Electronic Still Camera, a still camera which uses digital storage of its information. Can be compared to a film camera, which uses chemical media.

Exabyte: a type of data storage tape.

JAZ: A type of magnetic storage media made by the Iomega Corporation.

Layback: A term used to describe the distance at which a towed vehicle follows either a surface ship or a depressor weight.

LBL: Long Baseline Acoustic navigation system.

Macintosh: A type of personal computer

MIS: Marine Imaging Systems, the vendor who produced the ESC used during the Derbyshire survey. A subsidiary of the Marquest Group.

Navigation/Control Computer: An IBM compatible PC used to display and transmit data from all the navigation systems used on the ship/vehicle systems, and to send data to both the ship and vehicle control systems

Portmaster: A device made by Livingston, Inc, which multiplexes RS-232 data onto an ethernet stream.

Serial Data: for the purposes of this report, that data which is represented as a time series, and sent to a data logging computer over an RS-232 line.

SGI: Silicon Graphics Incorporated, a vendor of Unix-based workstations frequently used for data visualization.

SMPTE: The Society of Motion Picture and Television Engineers, the promulgator of standards for video systems.

Sonar Workstation: One of two Sparc workstations used to collect and process data from the DSL-120 and 200 sonar systems. One of these workstations was located in the control van (the Sonar Logging workstation) and the other in the Main Lab (The Sonar Processing workstation).

Sparc: a specific computer architecture marketed and sold by Sun Microsystems. The data logging, processing, and sonar collection workstations were all sparc-based.

Sun: Sun Microsystems, a vendor of Unix-based workstations

Tar: A tape archiving format used primarily in the Unix operating system.

Unix: A type of computer operating system

UTM: Universal Transverse Mercator, a map projection system.

Vehicle Topside Computer: An embedded, transputer based processor which communicates with subsea computing systems on both Jason and Argo, and routes data between those subsea systems and other topside systems which need the data.

WHOI: The Woods Hole Oceanographic Institution

APPENDIX C: ELECTRONIC STILL CAMERA PROCESSING

This appendix shows examples of processing of electronic still camera imagery in a number of different ways. For each set, the normalized image is shown in (a). Second, the image as processed during the survey is shown (b). Then, the results of passing the normalized images through alternate sets of parameters are shown (c), (d), and (e). The parameters used in the processing are indicated in the caption, where n indicates the number of contextual regions, t indicates the histogram type (0 is none, 1 is uniform, 2 is exponential, and 3 is Rayleigh), and a indicates alpha. A simple clip with a limit of 5 was used for all the images.

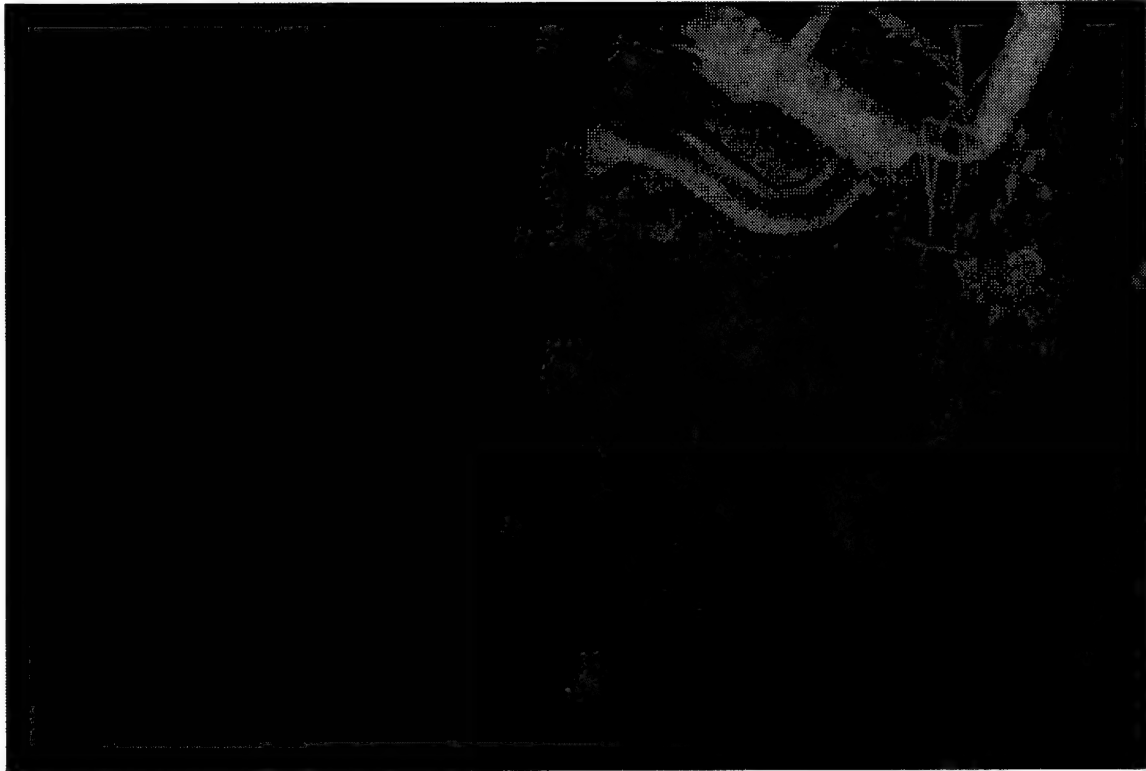
Tape 007, Image 455



a) *Normalized Image 455*



b) Image 455 as processed during survey ($n=3$, $t = 3$, $a=0.6$)



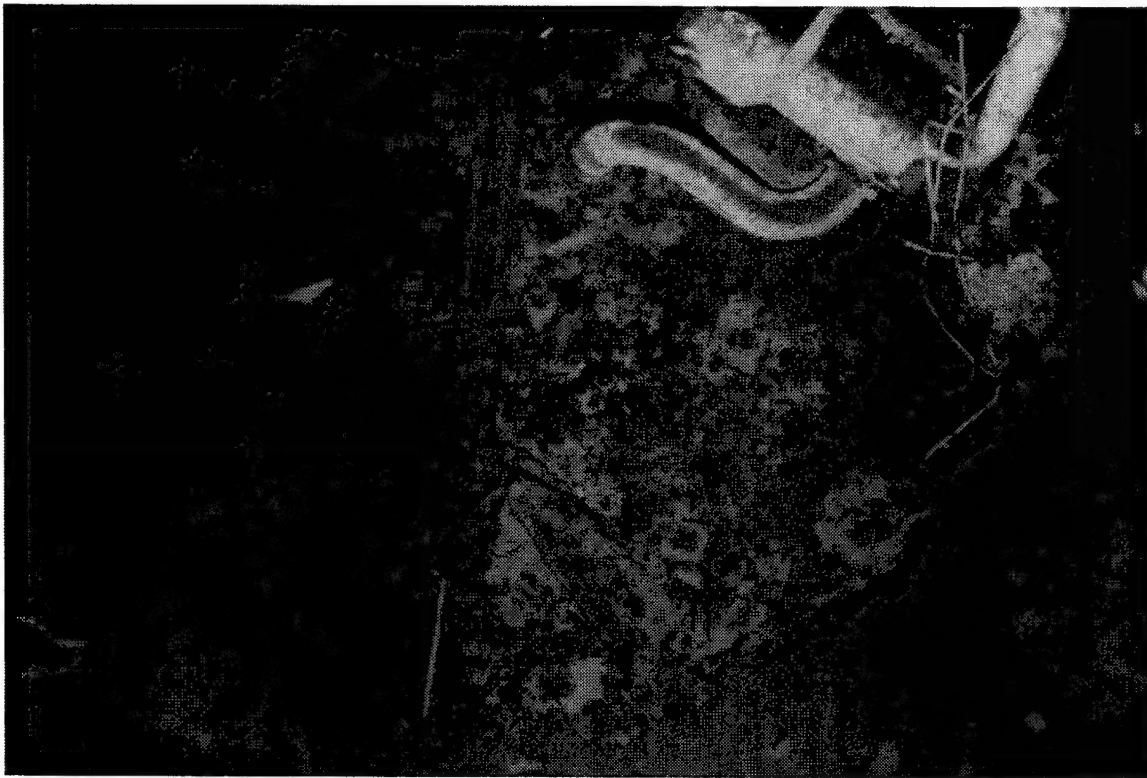
c) Image 455, $n=3$, $t=3$, $a=0.3$



d) Image 455, $n=12$, $t=3$, $a=0.9$

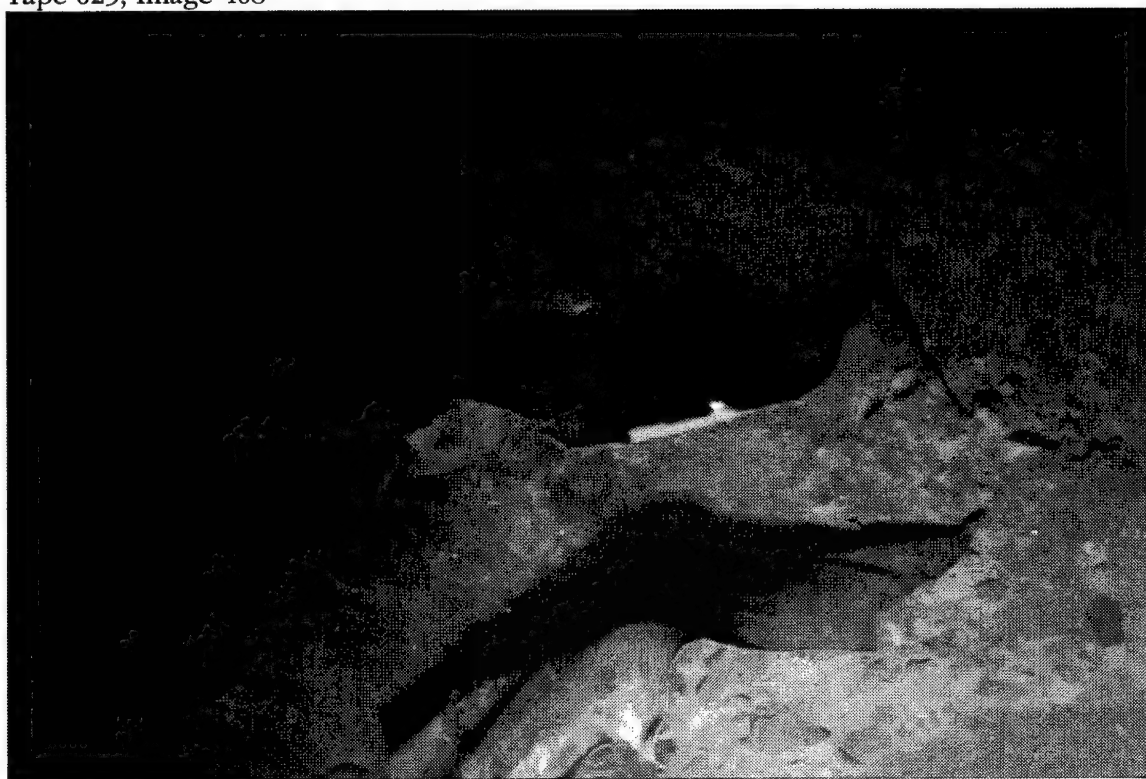


e) Image 455, $n=3$, $t=2$, $a=0.9$



f) Image 455, $n=3$, $t=1$, $a=0.9$

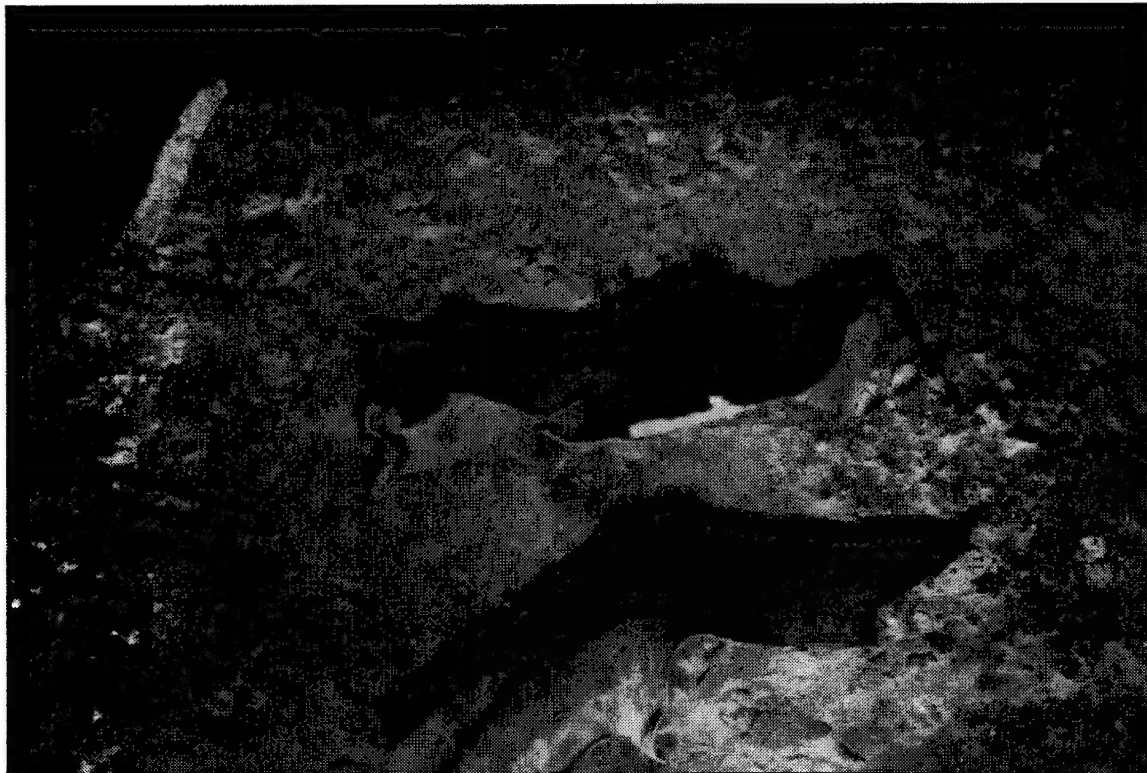
Tape 025, Image 408



a) Normalized Image 408



b) Image 408 as processed during survey ($n=3$, $t=3$, $a=0.6$)



c) Image 408, $n=3$, $t=3$, $a=0.3$



d) Image 408, $n=12$, $t=3$, $a=0.9$



e) Image 408, $n=3$, $t=2$, $a=0.9$



f) Image 408, $n=3$, $t=1$, $a=0.9$

Tape 031, Image 779



a) Normalized Image 779



b) Image 779 as processed during survey ($n=3$, $t=3$, $a=0.6$)



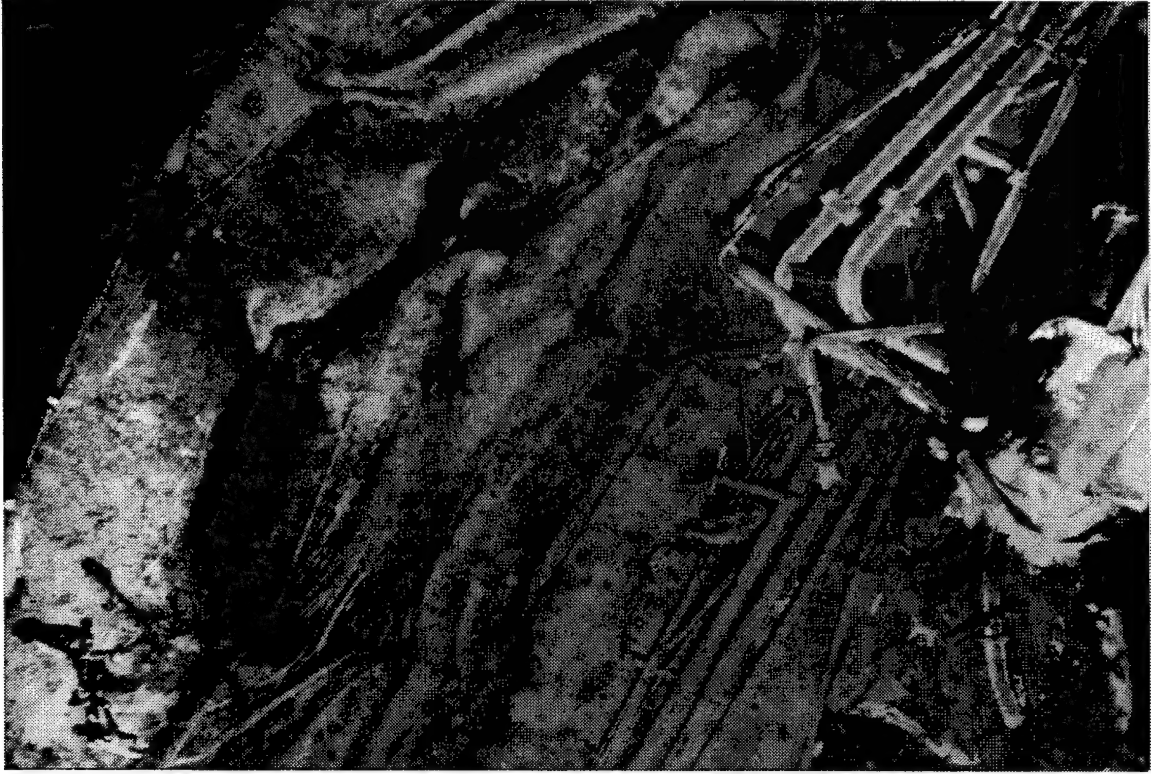
c) Image 779, $n=3$, $t=3$, $a=0.3$



d) Image 779, $n=12$, $t=3$, $a=0.9$



e) Image 779, $n=3$, $t=2$, $a=0.9$



f) Image 779, $n=3$, $t=1$, $a=0.9$

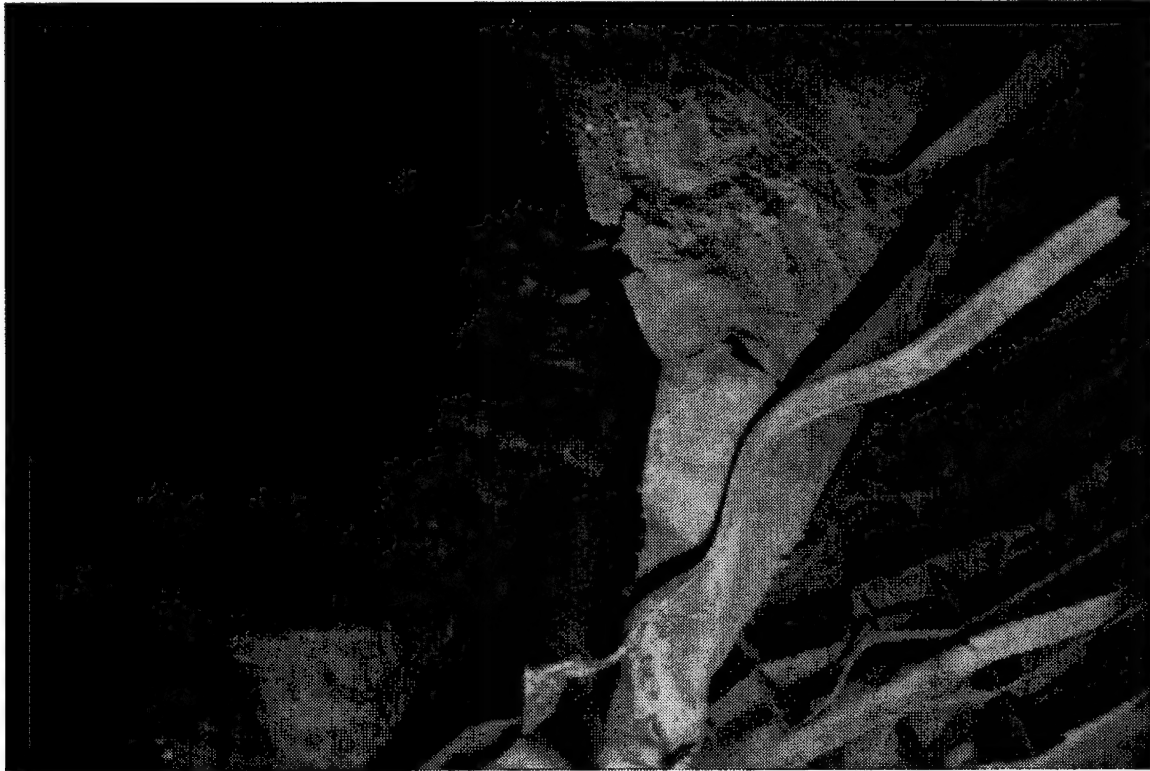
Tape 071, Image 1530



a) Normalized Image 1530



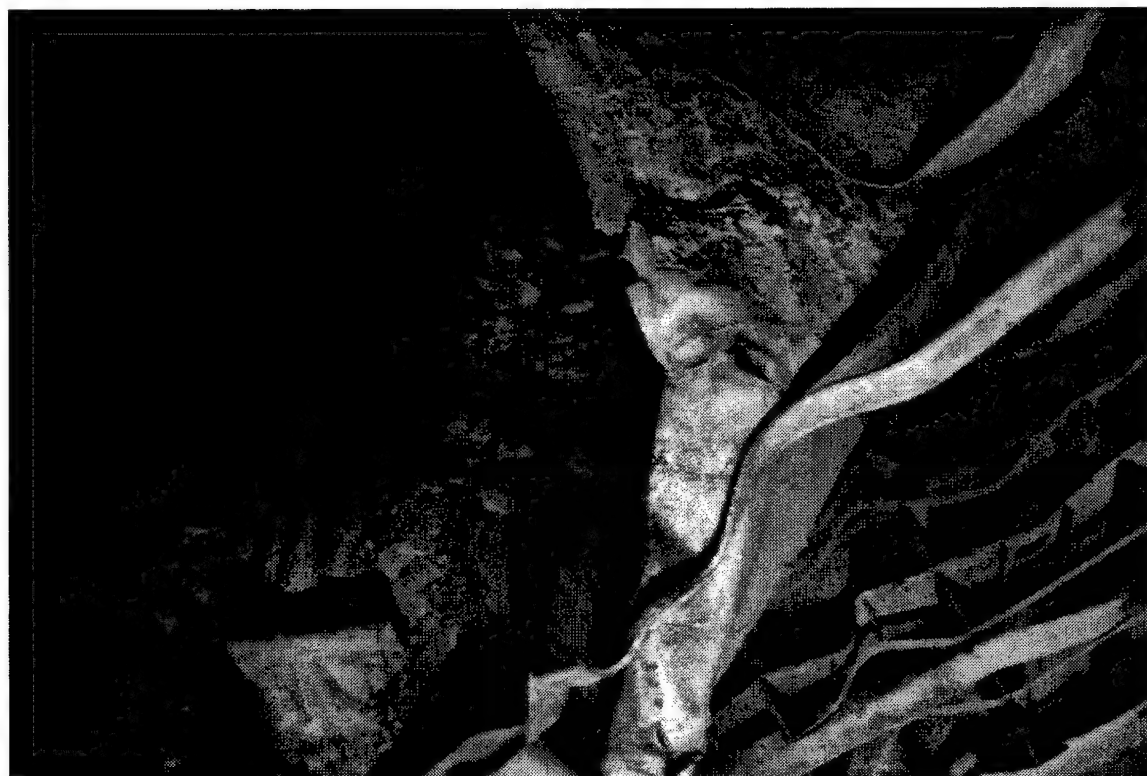
b) Image 1530 as processed during survey ($n=3$, $t=3$, $a=0.6$)



c) Image 1530, $n=3$, $t=3$, $a=0.3$



d) Image 1530, $n=12$, $t=3$, $a=0.9$

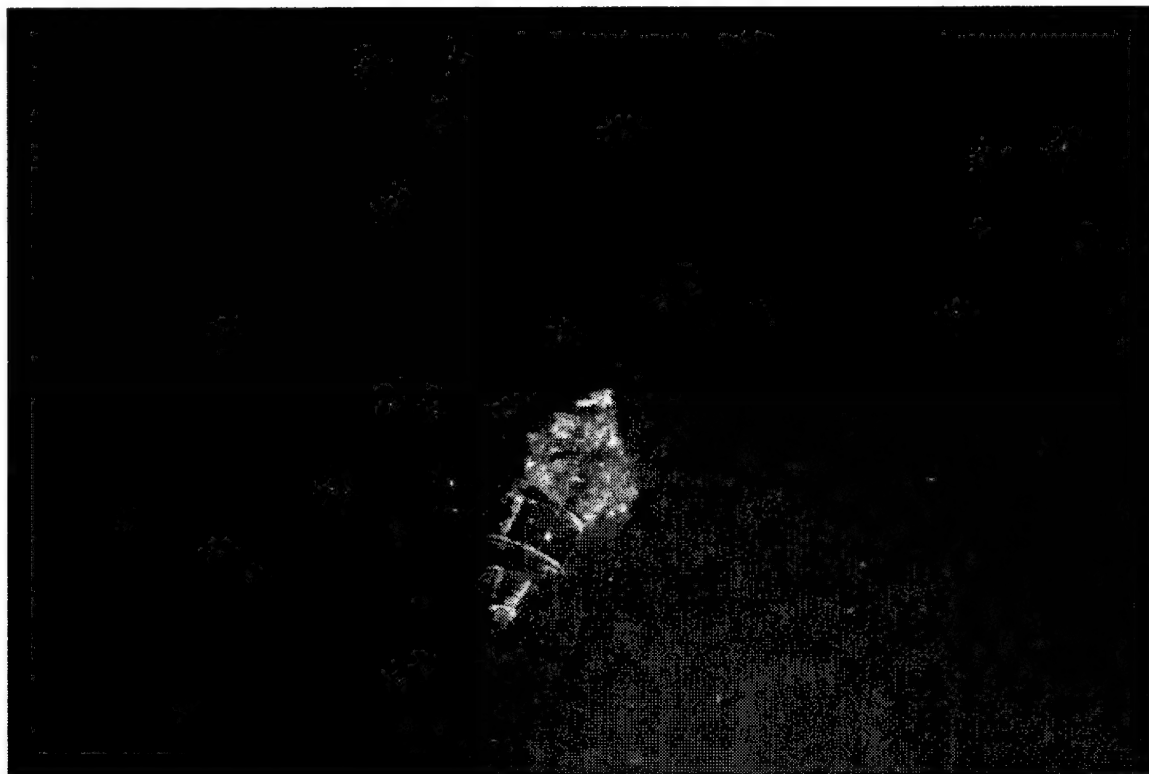


e) Image 1530, $n=3$, $t=2$, $a=0.9$



f) Image 1530, $n=3$, $t=1$, $a=0.9$

Tape 095, Image 1377



a) Normalized Image 1377



b) Image 1377 as processed during survey ($n=3$, $t=3$, $a=0.6$)



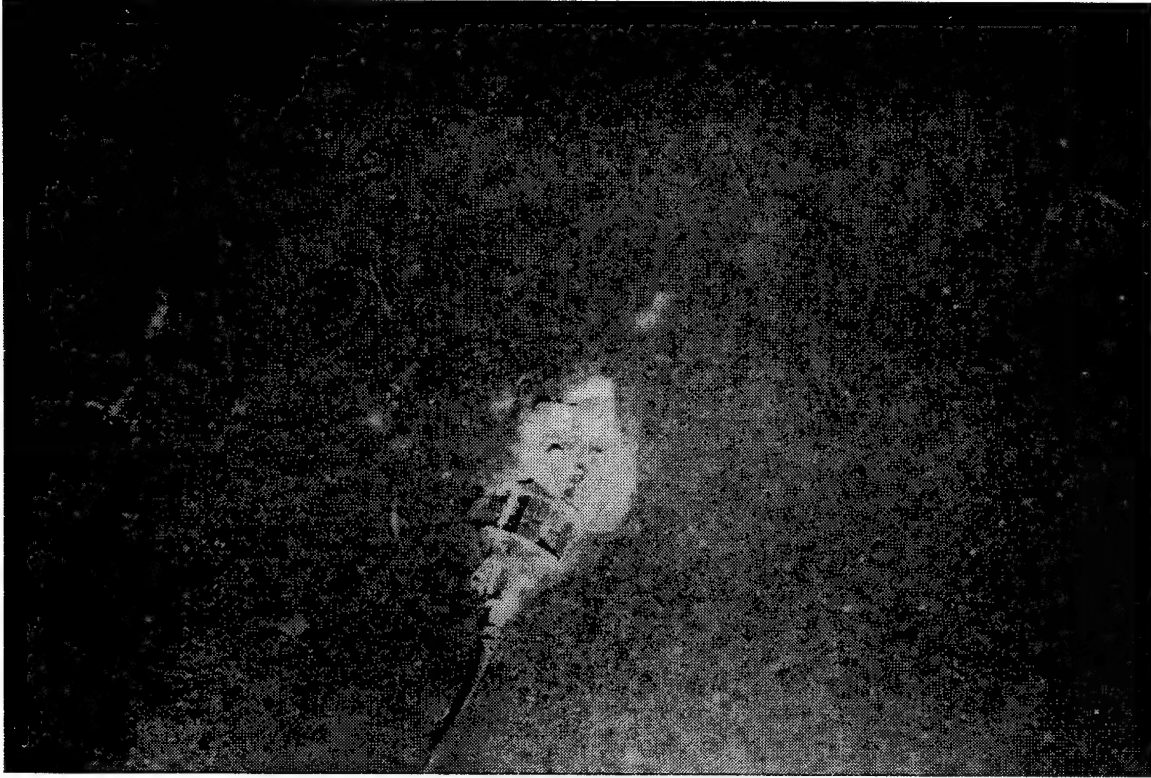
c) Image 1377, $n=3$, $t=3$, $a=0.3$



d) Image 1377, $n=12$, $t=3$, $a=0.9$



e) Image 1377, $n=3$, $t=2$, $a=0.9$



f) Image 1377, $n=3$, $t=1$, $a=0.9$

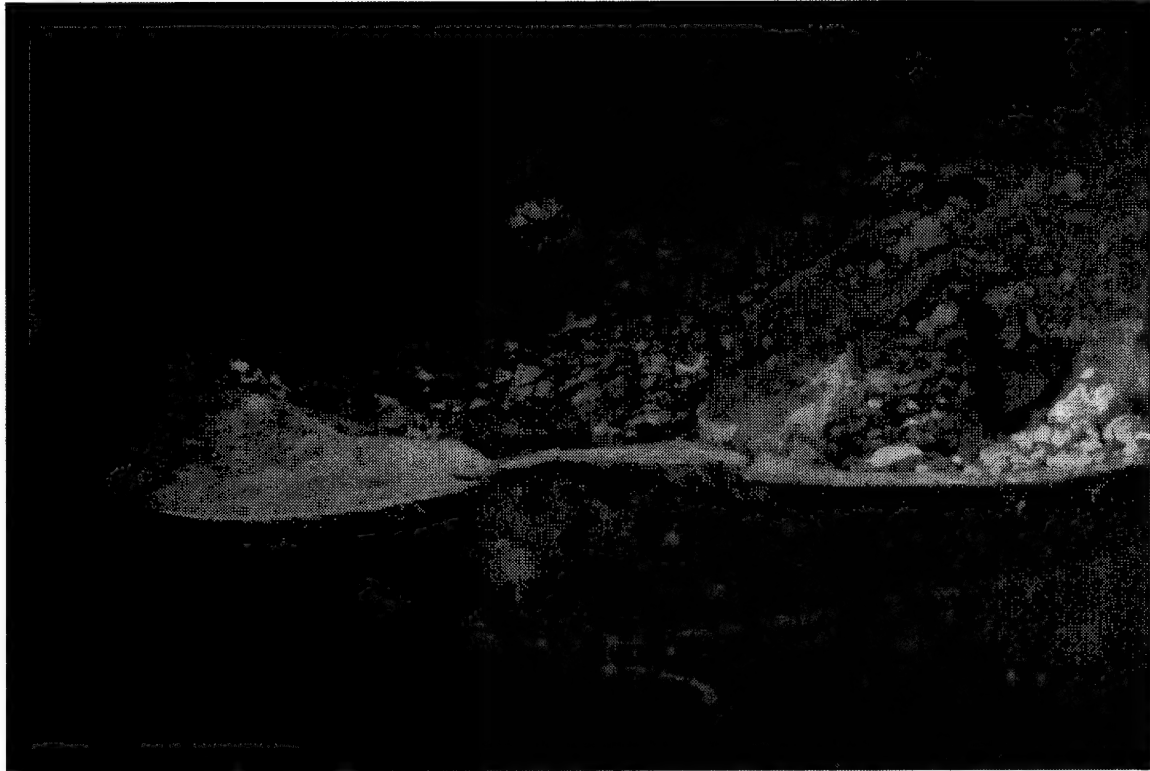
Tape 098, Image 362



a) Normalized Image 362



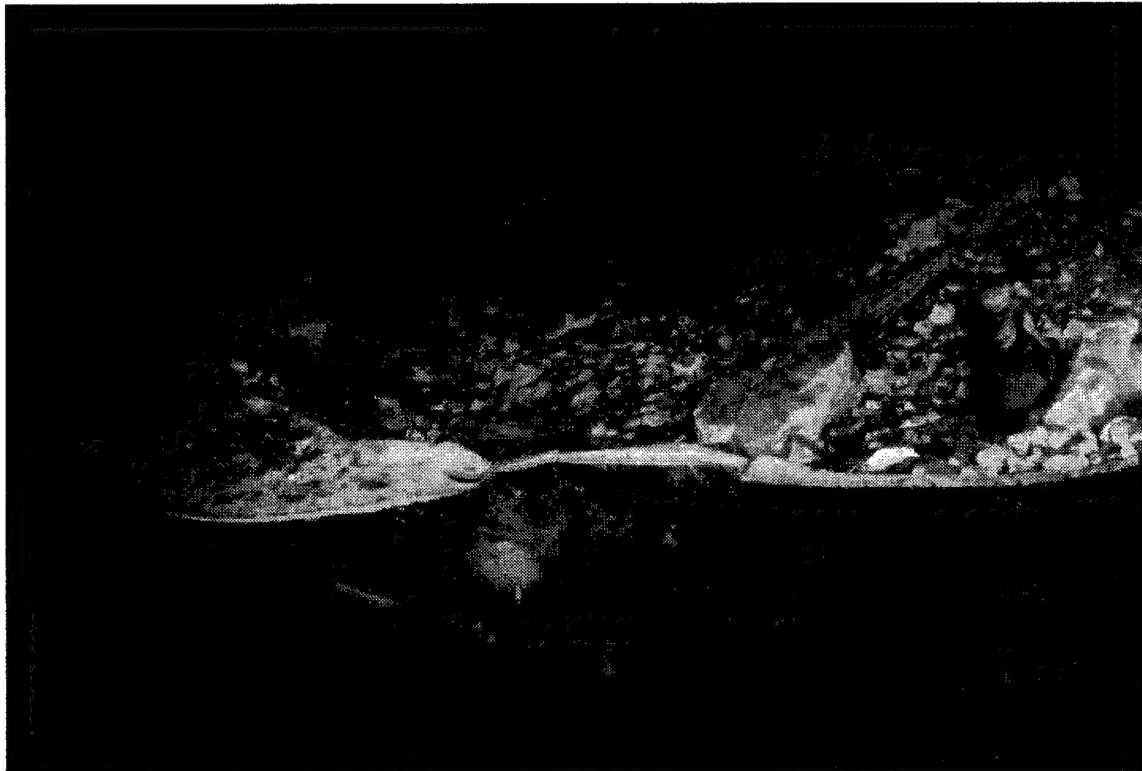
b) Image 362 as processed during survey ($n=3$, $t=3$, $a=0.6$)



c) Image 362, $n=3$, $t=3$, $a=0.3$



d) Image 362, $n=12$, $t=3$, $a=0.9$



e) Image 362, $n=3$, $t=2$, $a=0.9$



f) Image 362, $n=3$, $t=1$, $a=0.9$

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